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Apparatus for the Direct Recording of Ultrasonic Attenuation in Solids

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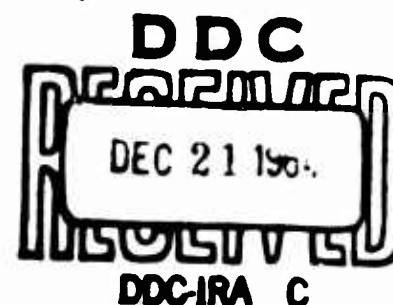
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Solid State Physics

June, 1964

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APPARATUS FOR THE DIRECT RECORDING OF
ULTRASONIC ATTENUATION IN SOLIDS

by

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June, 1964

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A considerable effort in this laboratory is devoted to the measurement of acoustic losses in solids, primarily single crystals, at ultrasonic frequencies. Examples include a study of the temperature dependence of ultrasonic attenuation in single crystal Strontium Titanate¹ and an investigation of the low temperature magnetic field losses in Copper, Silver and the ordering alloy Cu₃Au.² Experiments have been performed in this laboratory over the frequency range 10-1000 mc/sec. Other investigators³ have worked at frequencies up to 24 kmc/sec.

In this type of experiment a pulse of r-f energy excites a quartz transducer bonded to the sample which in turn sends a pulse of ultrasound through the sample.⁴ The acoustic pulse is reflected from the sample end, travels back to the transducer and the reciprocal effect occurs. An r-f voltage is induced in the transducer proportional to the amplitude of the acoustic echo. A series of these "echoes" is received which exhibits an exponential decay - the decrement being a measure of the attenuation, (Fig. 1). The attenuation can be written as:

$$A = \frac{1}{2(n_b - n_a)L} \ln \left(\frac{V_a}{V_b} \right) \text{ nepers/cm.} \quad (1)$$

where: n_a , n_b and V_a , V_b are the echo numbers and their amplitudes respectively, and L is the sample length.

As a basic unit for this measurement we use the Sperry

Ultrasonic Attenuation Comparator.⁵ This unit is a combination transmitter-receiver capable of delivering rf pulses over the frequency range 10-200 mc, containing a 60 mc heterodyne receiver with 8 mc bandwidth, and a calibrated exponential wave generator for attenuation measurements. We have extended the instrument to higher frequencies by incorporating General Radio Unit oscillators as local oscillators, and a series of JVM cavity oscillators⁶ to supply the transmitter pulse.

In addition, apparatus has been added, based upon a suggestion by B. B. Chick of Brown University^{7,8} for automatically recording acoustic attenuation as a function of some desired parameter as shown in Figure 2. Since the attenuation is essentially the logarithm of the ratio of the amplitudes of any two echoes, the procedure is simply to choose two convenient ones, detect their peaks, logarithmically amplify these, and then take the difference which is plotted on the x-y plotter against the suitable parameter. Any two echoes may be chosen, not necessarily adjacent. For averaging, several sets may be used.

The circuitry for the apparatus is shown in Figures 3, 4, 5 and 6. The train of echoes (Fig. 1) from the video amplifier of the receiver is fed into the pulse selection units shown in Figure 3. This unit can provide a gating pulse of .5-4 μ sec duration and delayed up to 50 μ sec.

The two pulses selected are then amplified. (Fig. 4). Because of the technique used for peak detection it is important that the .02 mfd capacitor at the output of this section be low

leakage. Peak detection is accomplished by the 6AL5 in the Logarithmic amplifier section, (Fig. 5). The logarithmic amplifiers are 6GC7's and utilize a technique⁹ wherein the triode is connected in a diode-triode fashion thus giving the proper characteristic and some amplification.

The signal is then taken through a cathode follower to a differential amplifier. The latter uses a Philbrick K2W operational amplifier and exhibits good linearity and stability. To compensate for non-linearities in the receiver i-f amplifier, an AGC system is used to maintain one of the pulses at a nearly constant amplitude and refer the balance of the train to this amplitude. Also, a blanking system (Fig. 6) has been provided to intensify the two pulses used on the monitoring oscilloscope.

The absolute accuracy of the device is of the order of 5% with relative measurements of accurate to 1% or better. For typical samples (e.g. length 1/2 cm. sound velocity 5×10^5 cm/sec) attenuations ranging from nearly zero to approximately 15 db/cm can be measured. There are severe restrictions on sample size and geometry for accurate results. Specimens must have surfaces that are flat and parallel to nearly optical tolerances. In addition, the bond between transducer and sample must be carefully made. These problems have been widely discussed in the literature.¹⁰

Some typical results are shown in Figures 7, 8 and 9 for Strontium Titanate and Copper using this equipment. Such apparatus makes it possible to obtain accurate acoustic attenuation

data rapidly and easily. The system is simple to operate and relatively inexpensive.

REFERENCES

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2. R. S. Krogstad and R. W. Moss, Boeing Scientific Research Laboratories Progress Review D1-82-0123-2, Jan. 1962.
3. See for example: H. E. Bömmel and K. Dransfeld, Phys. Rev. Letters, 1, 234 (1958) and E. H. Jacobsen ibid 2, 249 (1959).
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6. J-V-M Manufacturing, Brookfield, Illinois.
7. B. B. Chick, private communication.
8. R. Truell, et al, WADD Report 60-920, Dec. 1960.
9. See for example: L. East and W. Parker, R.S.I. 31, 1222 (1960)
10. For a complete discussion see: W. P. Mason, Physical Acoustics and the Properties of Solids p. 98 ff D. Van Nostrand, Princeton (1958).

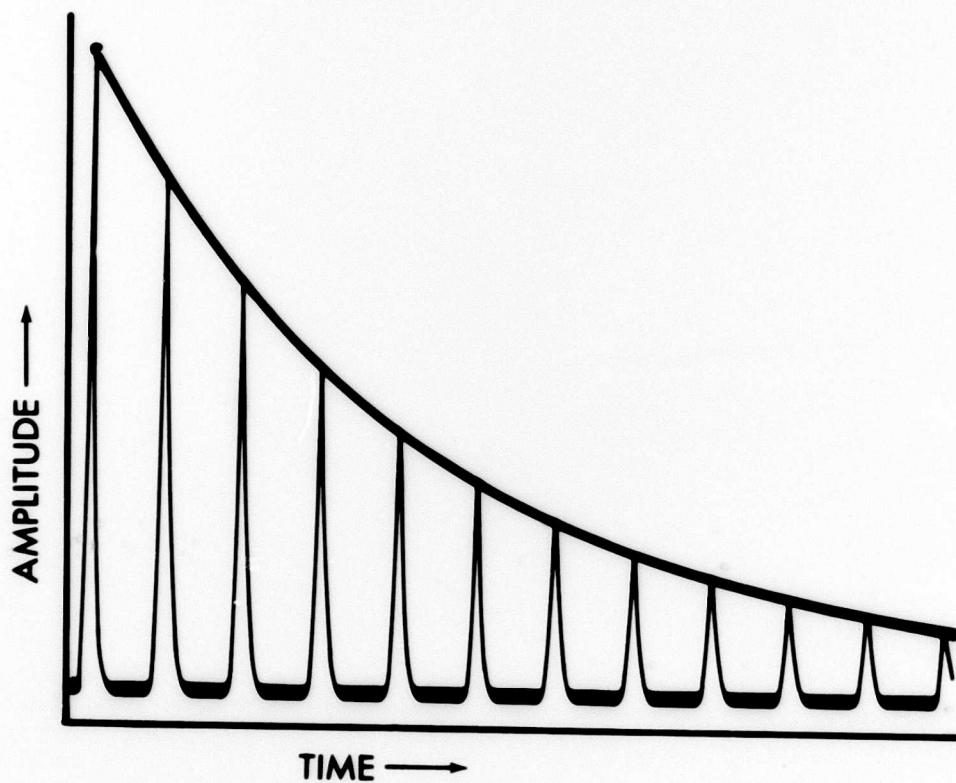
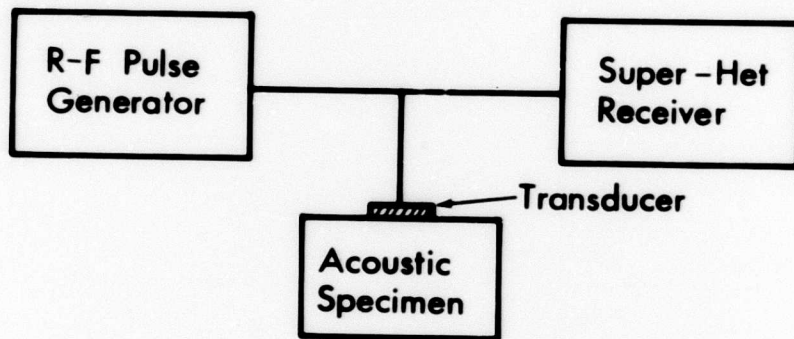


Figure 1 - Experimental set-up and exponential pulse train for typical "Pulse-Echo" ultrasonic study.

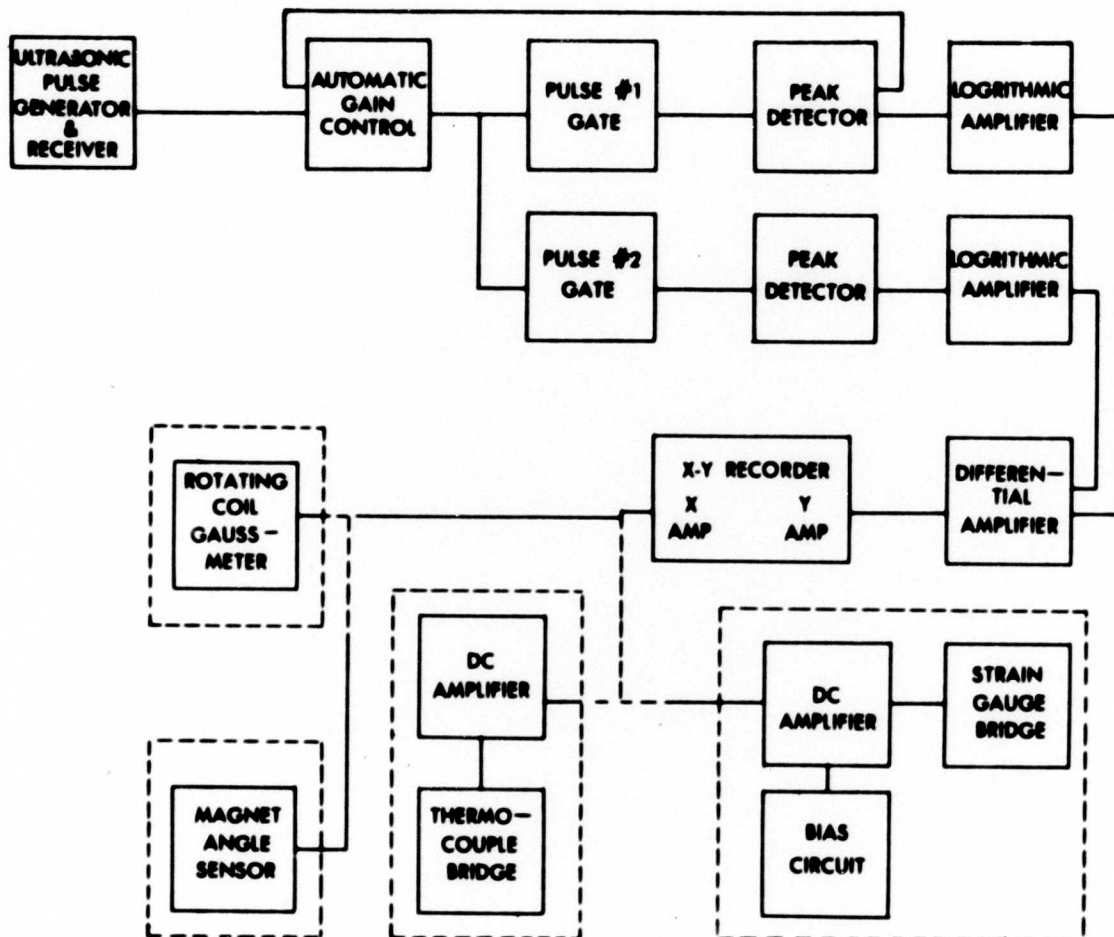


Figure 2 - Apparatus for the direct recording of ultrasonic attenuation in solids.

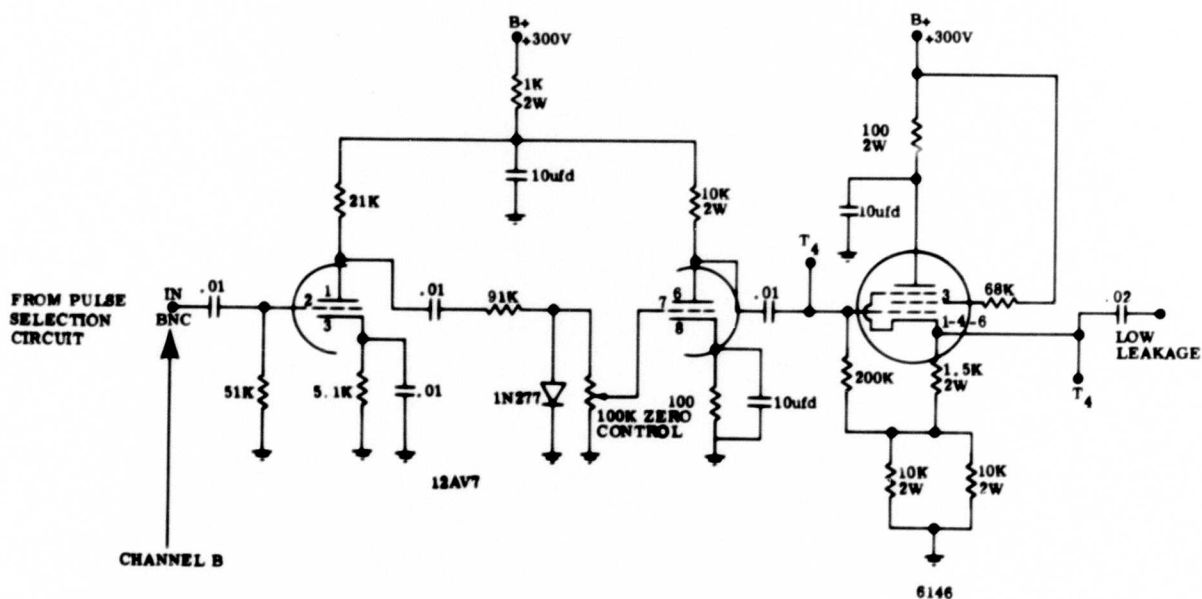
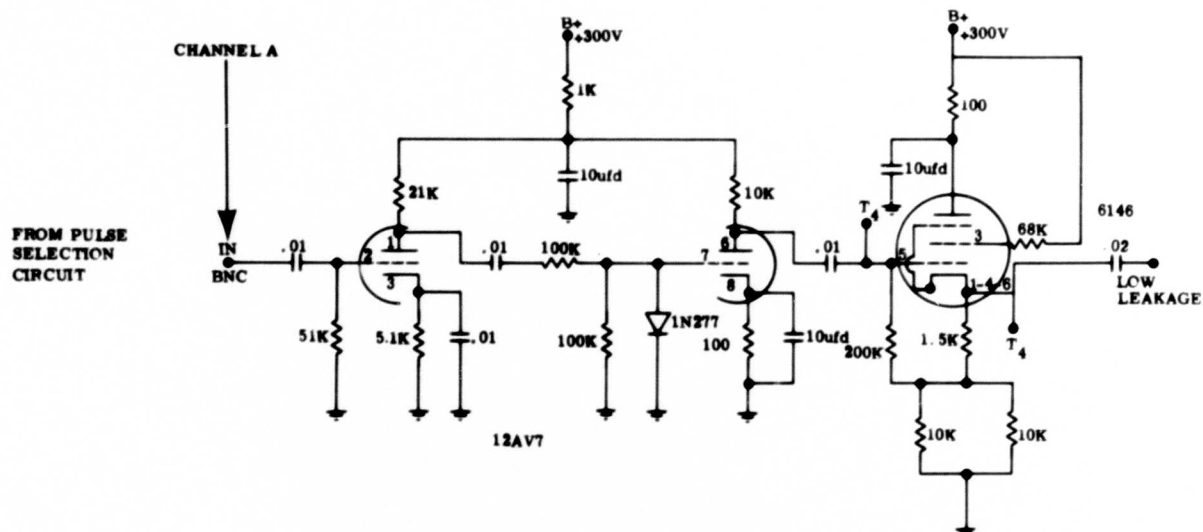
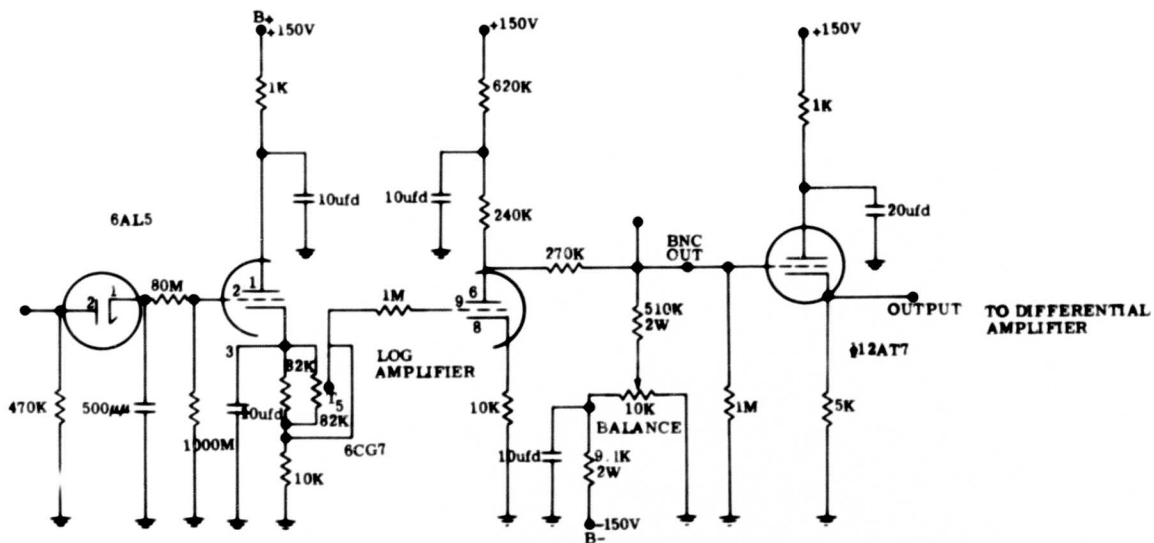


Figure 4 - Automatic attenuation plotter pulse amplifiers.



PEAK DETECTOR

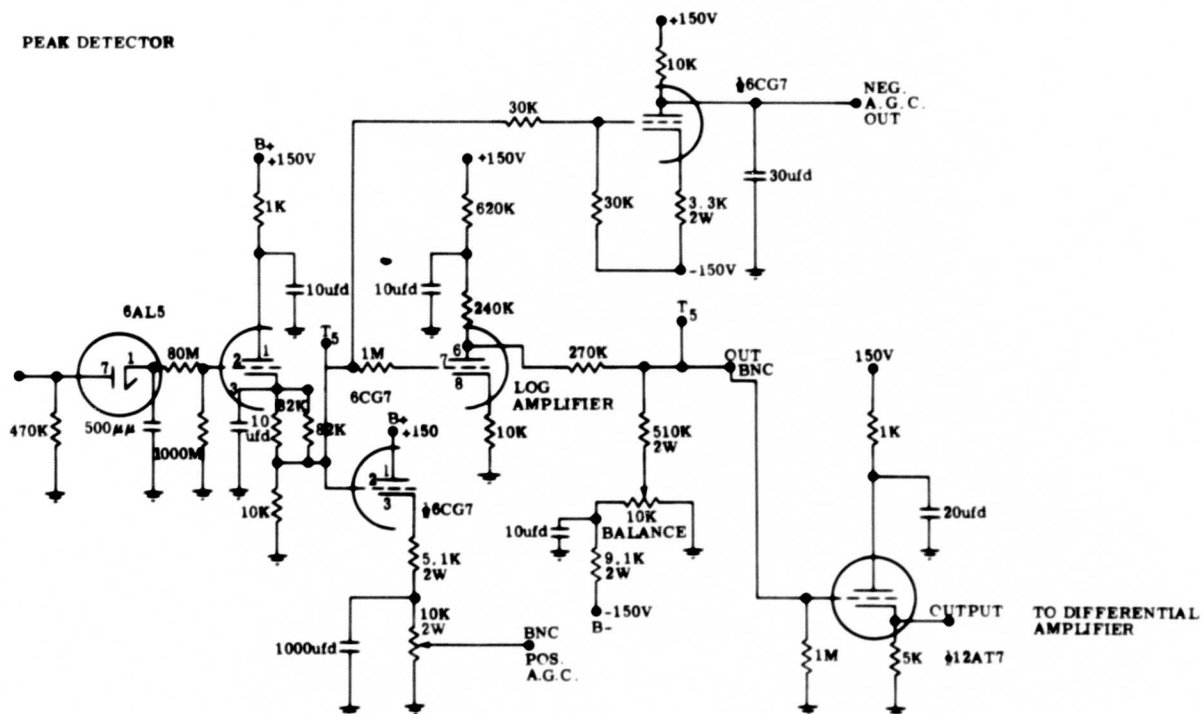


Figure 5 - Automatic attenuation plotter logarithmic amplifier section.

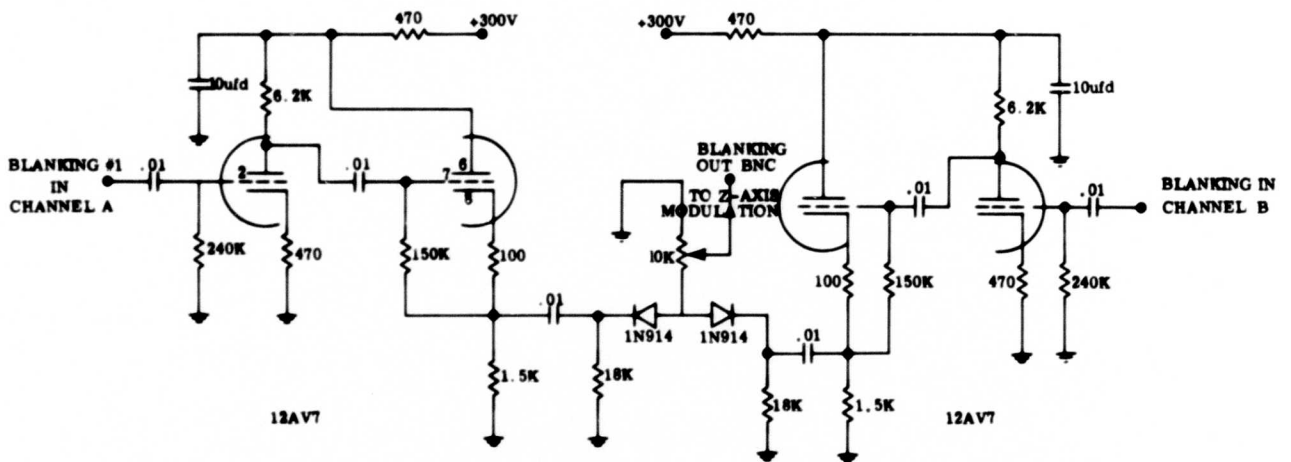


Figure 6 - Automatic attenuation plotter intensity modulation.

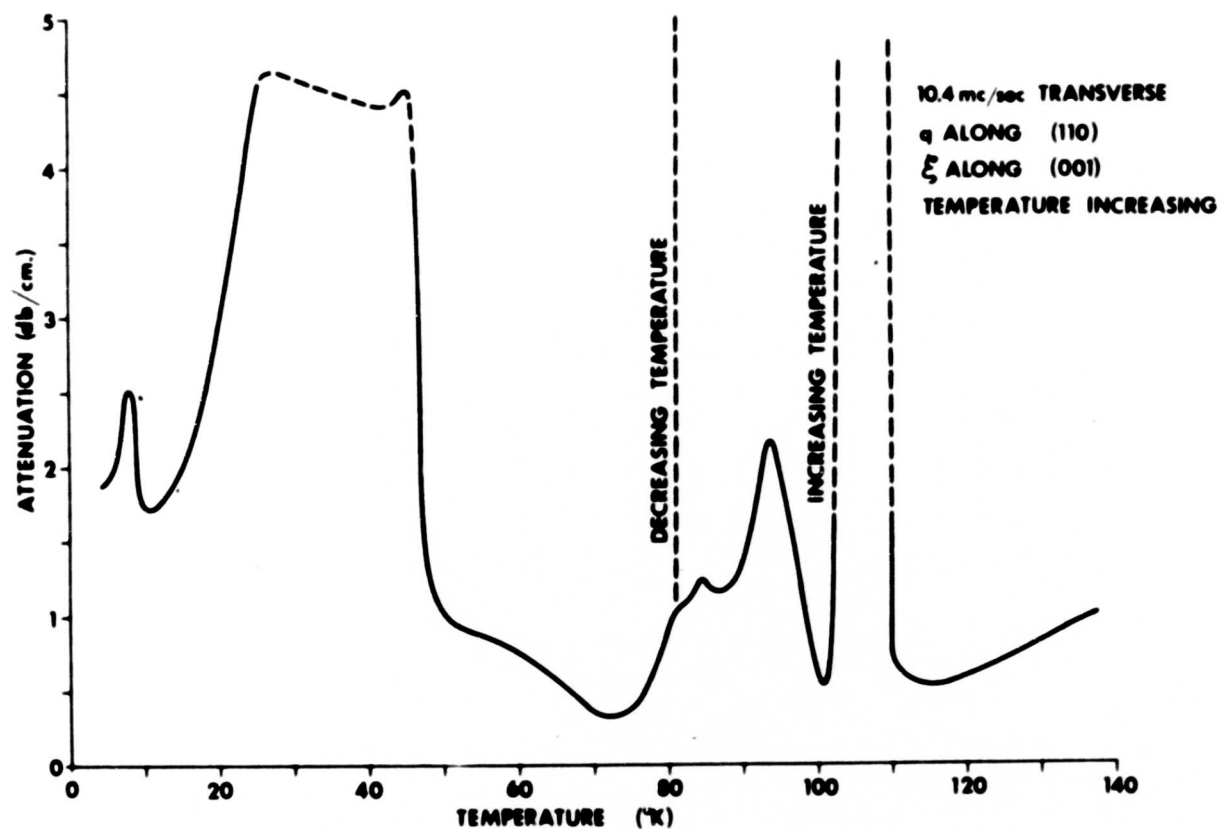


Figure 7 - Ultrasonic attenuation vs. temperature in SrTiO_3 at 10 mc, transverse wave.

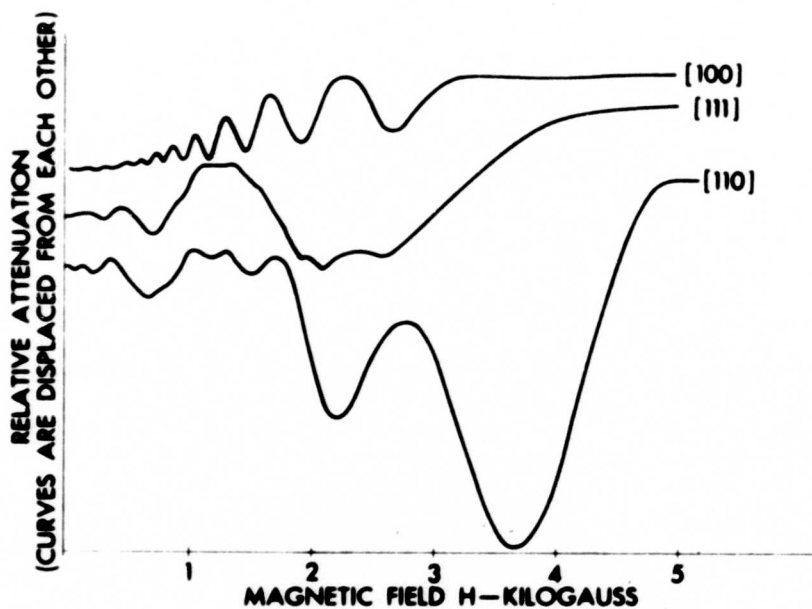


Figure 8 - Magnetic field dependence of ultrasonic attenuation in Copper at 150 mc, 4.2°K with sound propagation along the (110) crystallographic direction and perpendicular to H, showing periodicity and the effect of crystallographic direction.

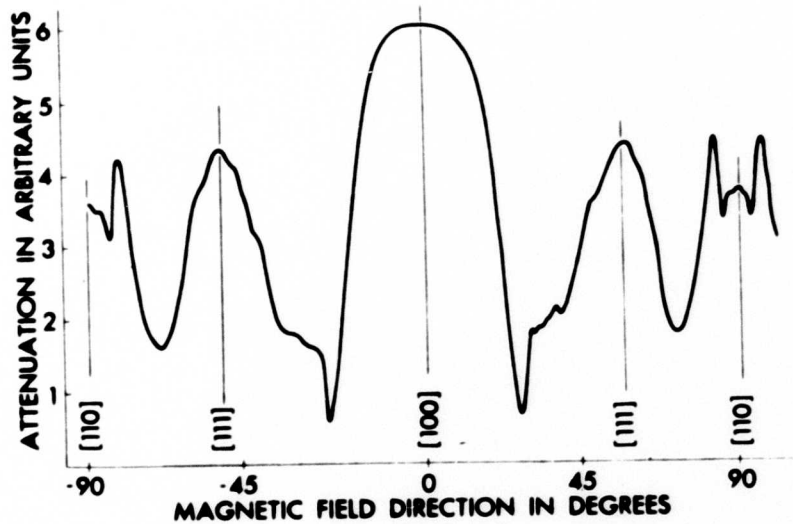


Figure 9 - Magnetic field direction dependence of ultrasonic attenuation in copper at 4.2°K and H 4000 gauss, with sound propagation along the 110 crystallographic direction perpendicular to H and at a frequency of 150 mc.